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SENSITIVENESS OF EXPLOSIVES TO FRICTIONAL IMPACT

BY

S. P. HOWELL

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SENSITIVENESS OF EXPLOSIVES TO FRICTIONAL IMPACT.

By S. P. Howell.

INTRODUCTION.

This publication, which has been prepared at the request of Dr. Charles E. Munroe, chairman of the committee on explosives investigations of the National Research Council, includes references to the sensitiveness of explosives, particularly potassium chlorate explosives, to frictional impact; describes the Bureau of Mines pendulum friction device and its tests of the device; defines the salient terms employed, particularly those used in classifying the explosives tested; and discusses the results of 370 tests.

The tests were made between September, 1911, and February 1, 1919, with a variety of permissible explosives, commercial explosives (other than permissible explosives), and military explosives (other than propellants).

SENSITIVENESS OF POTASSIUM CHLORATE EXPLOSIVES.

It has long been known that many commercial explosives may be exploded by severe and prolonged friction. It is also well established that some explosives are more sensitive to friction than others.

Certain kinds of potassium chlorate explosives have long been regarded as very sensitive to friction, as evidenced by the following quotations from Berthelot, Gody, Dupré, and Brunswig. Berthelot says:[a]

> Berthollet, after having discovered potassium chlorate and recognized the oxidizing properties so characteristic of this salt, thought of utilizing it in the manufacture of service powders. He made several attempts in this direction, but immediately suspended them after an explosion which happened during the manufacture carried on at the Essonnes powder factory—an explosion in which several persons were killed around himself. The same attempt has been revived at various periods, with certain variations in the composition.
>
> But in every case explosions, followed by loss of lives—such, for instance, as those which happened during the siege of Paris in 1870 and at L'École de Pyrotechnie in 1877—happened before long in the course of its manufacture.
>
> It is thus clear that potassium chlorate is an extremely dangerous substance, which is only natural, because its mixture with combustible bodies is sensitive to the least shock or friction.

---

[a] Berthelot, M. P. E., Explosives and their power, translated by C. N. Hake and William Macnab, 1892, p. 518.

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Gody says:[a]

> Berthollet missed losing his sight from the explosion of a chlorate explosive during imprudent manufacture in a mortar * * *.
>
> The mixture of combustible material with potassium chlorate must be made with the minutest precautions, as the least shock or friction may cause an explosion.

Dr. Dupré, as cited by De Kalb,[b] says:

> Chlorate of potassium, on account of the readiness with which it lends itself to the production of powerful explosives, offers a great temptation to inventors of new explosives, and many attempts have been made to put it to practical use, but so far with very limited success. This is chiefly owing to two causes. In the first place, potassium chlorate is a very unstable compound and is liable to suffer decomposition under a variety of circumstances, and under comparatively slight causes, chemical and mechanical. All chlorate mixtures are liable to what is termed spontaneous ignition or explosion in the presence of a variety of materials, more particularly of such as are acid, or are liable to generate acid; and all chlorate mixtures are readily exploded by percussion, such as a glancing blow which might easily and would often occur in charging a hole. In the second place, there is some evidence to show that the sensitiveness to percussion and friction increases by keeping, more especially if the explosive is exposed to the action of moist and dry air alternately.

Brunswig,[c] a more recent authority, in speaking of chlorate powders says:

> These powders have received little attention on account of their greater sensitiveness toward shock and friction. In more recent times, however, the preparation of chlorates and perchlorates by electrical methods has made these substances easy to obtain, and it has been discovered that the addition of fatty oils to chlorate mixtures decreases their sensitiveness.
>
> Various annual reports [d] of His Majesty's inspectors of explosives, Great Britain, record fires and explosions with various potassium chlorate explosives during the operation of sifting, mixing, ramming with wooden rammers, and ramming with bronze rammers.

A certain potassium chlorate explosive that is used in the United States and is designated "Chlorate explosive B" in this paper has come under suspicion because of premature explosions that occurred while it was used in bituminous coal mines. The details of these accidents are as follows:

1. While inserting copper needle in a charge in a tamped bore hole the charge exploded. Miner not injured.
2. This accident occurred less than one hour after accident 1, but in another room of the mine. The charge exploded while the copper needle was being inserted in the charge in a bore hole. Miner not injured.
3. While pushing a 12-inch cartridge into bore hole, with copper needle inserted about 6 inches in it, and just before charge reached back of bore hole, the charge exploded. Miner severely burned and hand badly lacerated.

---

[a] Gody, L., Traité théorique et pratique des matières explosives, 3 rd. ed., 1907, p. 240.

[b] De Kalb, Courtenay, Manual of explosives, 1900, p. 16.

[c] Brunswig, H., Explosives, translated and annotated by C. E. Munroe and A. L. Kibler, 1912, p. 302.

[d] 32d annual report, 1907, p. 114, 122; 33d annual report, 1908, p. 95; 34th annual report, 1909, p. 104; 36th annual report, 1911, p. 109.

Other potassium chlorate explosives containing potassium chlorate and sugar also exploded prematurely in coal mines in the United States. The details are as follows:

4. A 7-inch by 1-inch charge had misfired in a 5½-foot bore hole, presumably on account of using wet squibs. The stemming was then drilled out about 3 feet and copper needle inserted to re-form the needle hole. The needle went into the clay stemming easily and the miner "did not have to exert any strength to force it." He was turning the needle around to form the hole for the squib and just as the needle went through the stemming it turned to go a little bit faster, then the shot went off prematurely. The miner lost the thumb and index finger of his left hand, besides being lacerated about the chest and arms, and his face was slightly cut.

5. While a miner was tamping several inches of stemming on the explosive it exploded. No injury reported.

6. After putting in several handfuls of stemming on the explosive it exploded. The cartridge had been broken when being inserted. No injury reported.

7. Exploded while pushing the copper needle into the explosive. No injury reported.

In view of the frequency of these accidents and the seeming ease with which they took place, not being explainable by the sensitiveness of the explosive itself to friction, it was considered advisable to determine, if possible, the cause of the excessive sensitiveness to friction.

As the coal in the mines in which these accidents occurred contains pyrite-bearing bands, it was thought that the pyrite might be a general cause of the accidents, as practically all bituminous coals, and especially those mined in Illinois, Indiana, western Kentucky, Kansas, Iowa, Missouri, Arkansas, and Oklahoma, have these pyritiferous bands.

At the suggestion of Clarence Hall, chief explosives engineer of the Bureau of Mines, the experiments described below were made to determine the effect of pyrite-bearing coal on the sensitiveness to friction of certain potassium chlorate explosives.

Chlorate explosive B, which failed to pass the pendulum friction test with the wood-fiber shoe dropped from the 1½-meter position, gave no unfavorable results in 10 trials when the wood-fiber shoe was dropped from the 1-meter position. Under the same conditions, but mixed with small pieces of pyrite-bearing bituminous coal, the explosive ignited in each trial. It was found also that ignition occurred when the height of fall was reduced to one-half and even to one-fourth of a meter.

Similar tests made with FFF black blasting powder and 40 per cent nitroglycerin dynamite gave no ignitions.

In order to determine whether the friction of a moving copper-wire needle in a bore hole would be sufficient to cause an ignition of chlorate explosive B, the following test was made.

A hole one-half inch in diameter and 4 inches deep was drilled in a block of bituminous coal. A 2-gram charge consisting of 4 parts of chlorate explosive B, 1 part coal dust, and 1 part pyrite of the same granulation as the explosive was placed in the bore hole. The friction from the movement of a No. 8 (B. & S. gage) copper needle within this mixture caused ignition.

Repeated with three other chlorate explosives of the same general type, this test gave the same results.

Similar tests with FFF black blasting powder and 40 per cent nitroglycerin dynamite gave no ignition.

An unpublished report by Russell B. and Treadway B. Munroe, which was available to the Bureau of Mines, on the effect of metallic sulphides on a sodium chlorate explosive showed that both antimony and lead sulphides increased the sensitiveness of the explosive to friction more than pyrite.

This conclusion is in part corroborated by the work of Cushman,[a] who shows that in priming compositions the compositions containing antimony or lead sulphides are more sensitive to impact than the composition containing pyrite.

REASONS FOR ADOPTING THE PENDULUM FRICTION DEVICE.

To determine the sensitiveness of potassium chlorate explosives, the English have long used the broomstick test. This test consists in spreading a small quantity of the explosive on a soft wood surface and striking it a glancing blow with a broomstick. An explosive is considered as having passed this test if it fails to explode or crack when tested repeatedly.

A rawhide-mallet test has been used at the Bureau of Mines and elsewhere to determine the sensitiveness of explosives. A small portion of the explosive is spread on a smooth oak surface and struck a glancing blow with the mallet. The explosive is considered as having passed this test if there is no explosion or local crackling.

Obviously the broomstick test and the rawhide-mallet test lack the uniformity in execution that should characterize a scientific friction test, so in June, 1911, the Bureau of Mines designed a pendulum friction device. The first tests with it were made in September, 1911. Tests of a variety of explosives, including permissible explosives, commercial explosives other than permissibles, black blasting powder, and potassium chlorate explosives, showed that all explosives except a certain potassium chlorate explosive passed the test.

In October, 1911, a committee consisting of Dr. C. E. Munroe, C. P. Beistle, and Clarence Hall was appointed to pass upon the propriety of the pendulum friction test as a requirement for determining the permissibility of explosives for use in coal mines.

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[a] Cushman, A. S., Antimony sulphide as a constituent in military and sporting arms primers; Jour. Ind. and Eng. Chem., vol. 10, 1918, p. 376.

After studying the results of the preliminary tests, and witnessing tests of the pendulum friction device provided with a wood-fiber shoe, the committee recommended the adoption of the test. Their report was approved by Director J. A. Holmes on November 22, 1911.

In the opinion of the director and the committee, the failure of an explosive to pass the pendulum friction test as adopted by the Bureau of Mines should be considered an unfavorable physical characteristic because of the liability of such an explosive to explode in drill holes by such friction as may be produced by a tamping rod. Moreover, they decided that the Bureau of Mines was not warranted in placing on the permissible list any explosive that failed to pass the pendulum friction test, but did pass other required tests.

DESCRIPTION OF THE DEVICE.

The pendulum friction device adopted by the Bureau of Mines (see Pl. I, Pl. II, and fig. 1) comprises a steel anvil and a swinging shoe. The anvil has a smooth face, 3.25 inches (8.3 cm.) wide by 12 inches (30.5 cm.) long, in the middle of which are three grooves for holding the charge of explosive. The shoe is 3¼ inches (8.3 cm.) wide, its radius of swing is 6 feet, 6.75 inches (2 meters), and the radius of curvature of its face is 10.5 inches (26.7 cm.). The shoe may be of steel, or of steel faced with hardwood fiber or other material, and may be dropped from heights up to 78.7 inches (2 meters). Added weights of 2.2 to 44 pounds (1 to 20 kg.) may be used in the tests.

METHOD OF TEST.

In the official test adopted by the Bureau of Mines a steel shoe faced with hardwood fiber, 44 pounds (20 kg.) added weight and a fall of 59.1 inches (1.5 meters) are used. The shoe is squarely adjusted so that when there is no explosive on the anvil it will swing across the face of the anvil 18 ± 1 times before coming to rest.

In making the test 7 grams of the explosive is spread in an even layer in and above the three grooves in the anvil. Each test consists of 10 trials. After each trial the remaining explosive is brushed from the anvil and shoe, and both are thoroughly cleaned with a solvent to insure the complete removal of the explosive. When the steel shoe is used, both the shoe and anvil after each trial are rubbed with carborundum cloth to remove any roughness caused by the preceding trial; thus any gritty material is thoroughly removed.

The usual tests are made at normal temperatures (14° C. to 30° C.), the temperature of the anvil and of the shoe being controlled.

The observations made are explosion, whether complete or partial; burning; local crackling, whether distinctly audible or almost indistinguishable; and no local crackling. An explosive that gives no more unfavorable result than an almost indistinguishable local crackling with the wood-fiber shoe is considered as having passed the test.

As soon as tests showed that the steel shoe was more severe than the wood-fiber shoe, explosives were first tested with the steel shoe and usually were not tested on the wood-fiber shoe if they passed the test with the steel shoe.

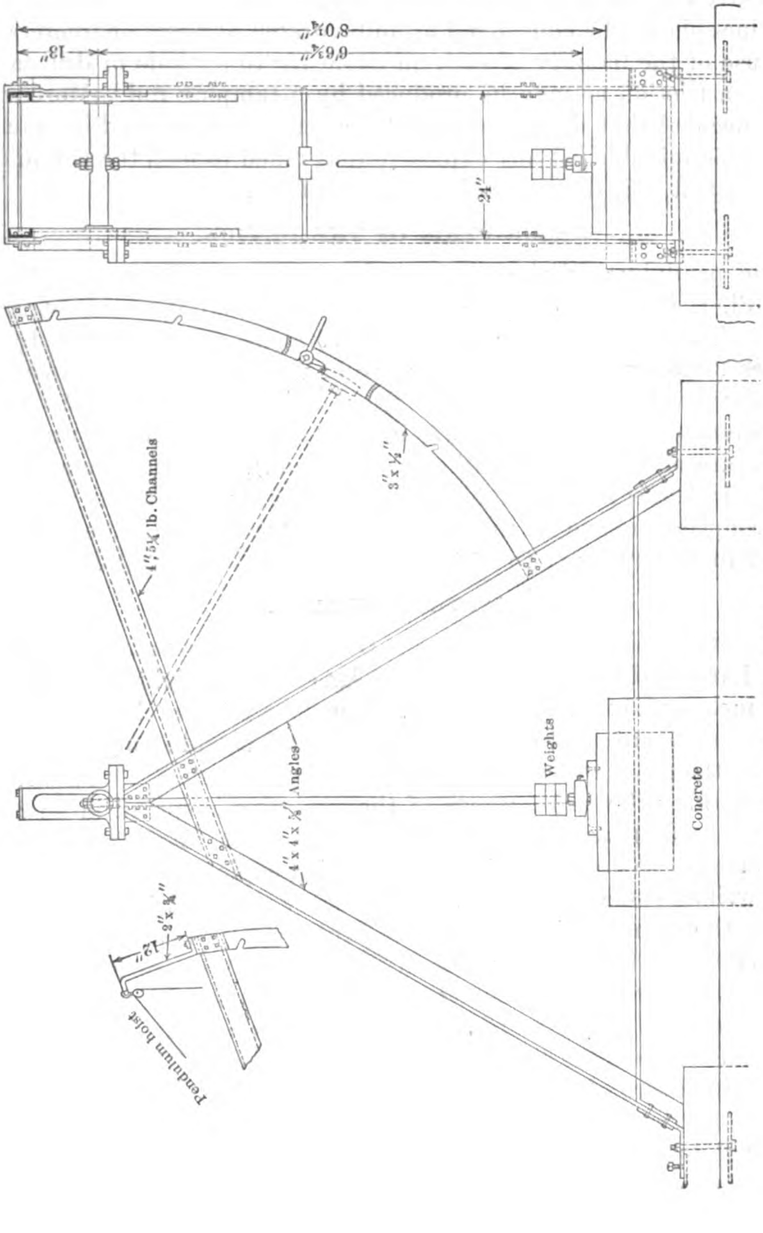
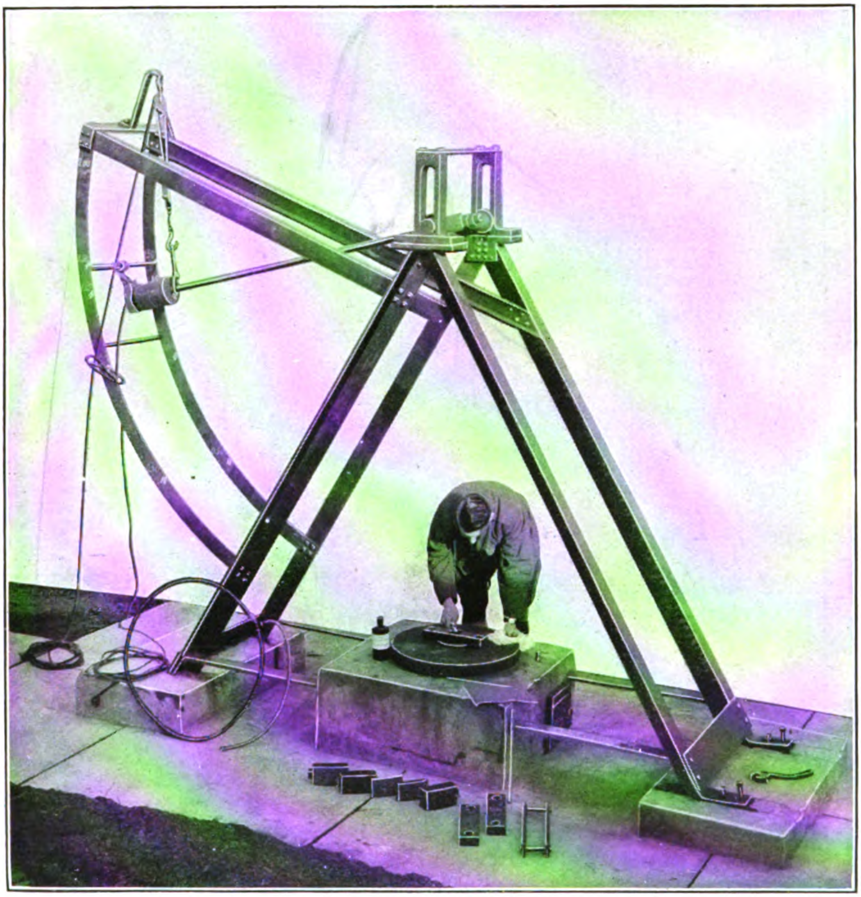
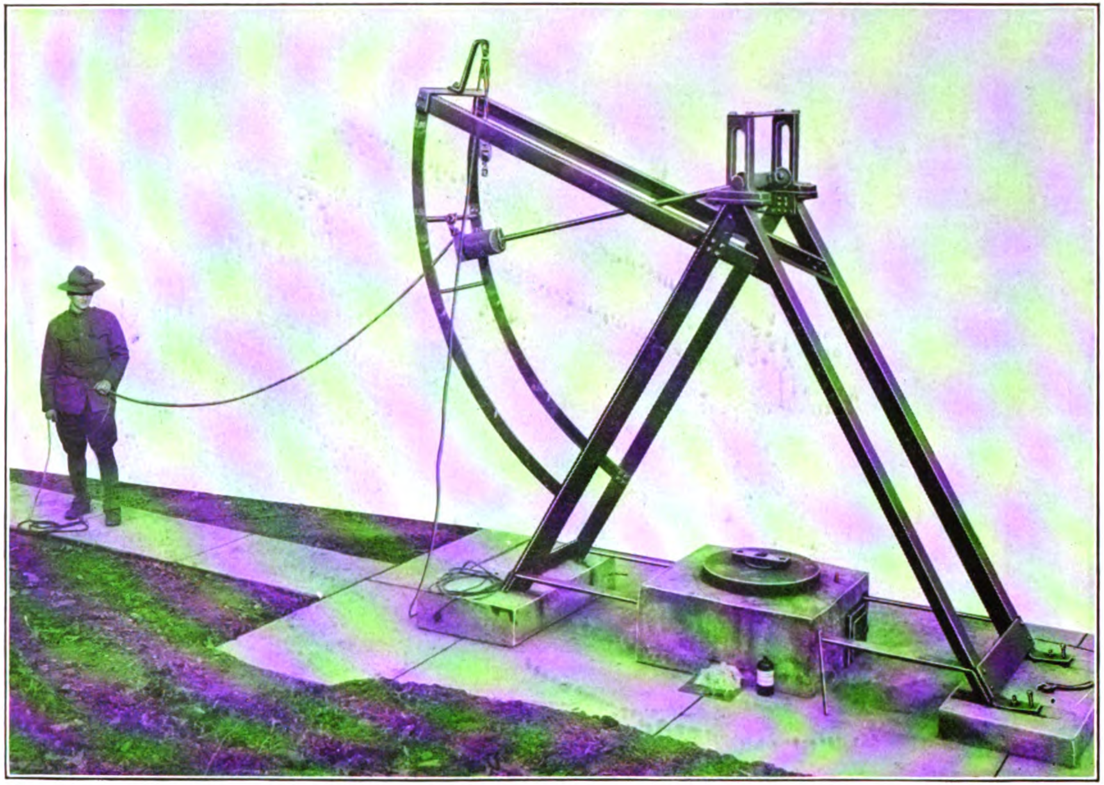


FIGURE 1.—Elevation and details of pendulum friction device.



PENDULUM FRICTION DEVICE, PREPARING FOR TEST.



PENDULUM FRICTION DEVICE, READY FOR MAKING TEST.

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DEFINITIONS OF TERMS.

A number of terms used in Bureau of Mines publications are defined below.

Permissible explosives.—Explosives that have passed the tests required for permissibility and have been placed on the Bureau of Mines permissible list.

Nonpermissible.—Explosives that were submitted for the permissibility tests but failed to pass.

Class 1a, Ammonium nitrate explosives.[a]—Explosives in which the characteristic ingredient is ammonium nitrate, containing a sensitizer that is in itself an explosive.

Class 2, Hydrated explosives.[a]—Explosives in which salts having water of crystallization are the characteristic ingredient.

Class 3, Organic nitrate explosives.[a]—Explosives in which the characteristic ingredient is an organic nitrate other than nitroglycerin.

Class 4, Nitroglycerin explosives.[a]—Explosives in which the characteristic ingredient is nitroglycerin.

Straight dynamite.—An explosive that contains the stated percentage of nitroglycerin.

Strength dynamite.—The manufacturer's nominal rating as equivalent to the stated percentage of straight dynamite.

L. F.—Low freezing.

V. L. F.—Very low freezing.

X. V. L. F.—Extra very low freezing.

Ammonia dynamite.—A dynamite in which part of the nitroglycerin has been replaced by ammonium nitrate.

Potassium chlorate explosive.—An explosive in which the characteristic ingredient is potassium chlorate.

Perchlorate explosive.—An explosive in which the characteristic ingredient is a perchlorate.

Black blasting powder.—A granulated explosive containing sodium nitrate, charcoal, and sulphur.

Black ignition powder.—A finely granulated potassium nitrate military powder.

RESULTS OF TESTS.

The results of tests of samples of explosives manufactured in the United States, the tests being made with the wood-fiber shoe and the steel shoe, with 44 pounds added weight, with a fall of 1.5 meters and at normal temperatures, are given in Table I.

---

[a] These terms are applied only to permissible and nonpermissible explosives.

TABLE I.—*Pendulum friction tests of domestic explosives.*

Designation of group.	**Wood-fiber shoe.** Number of explosives.			**Steel shoe.** Number of explosives.		
	Tested.	Passed.	Failed.	Tested.	Passed.	Failed.
Permissible:						
Class 1a	9	9	0	60	59	1
Class 2	1	1	0	8	8	0
Class 3	3	3	0	3	3	0
Class 4	14	14	0	56	46	10
Nonpermissible:						
Class 1a	4	4	0	16	16	0
Class 3	2	2	0	4	4	0
Class 4	1	1	0	5	5	0
Black blasting powder	2	2	0	7	7	0
Blasting gelatin	1	1	0	1	1	0
Gelatin dynamite:						
35 per cent strength	1	1	0	1	0	1
35 per cent strength, V. L. F	1	1	0	1	0	1
40 per cent strength	3	3	0	4	1	3
40 per cent strength, L. F	1	1	0	1	0	1
40 per cent strength, V. L. F	1	1	0	1	0	1
40 per cent strength, X. V. L. F	2	2	0	2	0	2
60 per cent strength	1	1	0	1	0	1
Nitroglycerin dynamite:						
40 per cent straigth	5	5	0	4	1	3
Nitroglycerin dynamite, L. F.:						
40 per cent strength	1	1	0	1	0	1
Ammonia dynamite:						
40 per cent strength	1	1	0	1	1	0
Ammonia dynamite, L. F.:						
40 per cent strength	......	......	......	6	6	0
Organic nitrate (other than nitroglycerin):						
Propylene glycol dinitrate—						
Blasting gelatin	1	1	0	2	2	0
40 per cent strength	......	......	......	3	3	0
40 per cent strength gelatin	1	1	0	1	1	0
Nitro starch explosives—						
40 per cent strength	......	......	......	4	4	0
45 per cent strength	......	......	......	1	1	0
60 per cent strength	......	......	......	1	1	0
Grenade powder	1	1	0	......	......	......
Potassium chlorate explosives:[a]						
A	......	......	......	1	0	1
B	1	0	1	......	......	......
C	1	1	0	1	0	1
D	1	1	0	1	1	0
E	1	0	1	......	......	......
F	1	1	0	1	0	1
G	1	0	1	1	0	1
H	1	0	1	......	......	......
I	1	0	1	1	0	1
J	1	0	1	1	0	1
K	......	......	......	1	1	0
L	1	0	1	1	0	1
M	1	0	1	1	0	1
N	1	1	0	1	1	0
O	2	0	2	......	......	......
Black ignition powders:						
Grade A, No. 1	......	......	......	1	1	0
Special containing 2½ per cent perchlorates	......	......	......	1	1	0
Special containing 5 per cent perchlorates	......	......	......	1	1	0
Ammonal:						
American formula	......	......	......	1	1	0
English formula	1	1	0	1	0	1
Ammonium nitrate, T N T, and calcium silicide	1	1	0	1	0	1

[a] Ingredients of the explosives designated A, B C, etc., include:
- **A.** Nitroglycerin, pine tar, potassium chlorate, sodium nitrate, and ammonium nitrate.
- **B.** Potassium chlorate, sugar, and gum arabic.
- **C.** Potassium chlorate, sugar and starch.
- **D.** Potassium chlorate, sodium nitrate, sulphur, and paraffin.
- **E.** Potassium chlorate, sugar, and gum arabic.
- **F.** Potassium chlorate, dinitrotoluol, mononitronaphthalene, and castor oil.
- **G.** Potassium chlorate and nitrated resin.
- **H.** Potassium chlorate, sodium chloride, and cane sugar.
- **I.** Potassium chlorate, sodium nitrate, and sugar.
- **J.** Potassium chlorate, linseed oil, carbon, and starch.
- **K.** Potassium chlorate, sodium nitrate, sodium chloride, resin, nitrocellulose, and dinitrotoluol.
- **L.** Potassium chlorate, crude oil, cane sugar, and manganese dioxide.
- **M.** Potassium chlorate, cane sugar, and organic matter.
- **N.** Potassium chlorate, crude oil, cane sugar, and manganese dioxide.
- **O.** Potassium chlorate and cane sugar.

TABLE 1.—*Pendulum friction tests of domestic explosives*—Continued.

Designation of group.	Wood-fiber shoe. Number of explosives.			Steel shoe. Number of explosives.		
	Tested.	Passed.	Failed.	Tested.	Passed.	Failed.
Perchlorate explosives:[a]						
No. 1	1	1	0	1	0	1
No. 2	1	0	1	1	0	1
T N T:						
Grade I[b]	1	1	0	5	5	0
Grade II	1	1	0	2	2	0
Grade III	1	1	0	1	1	0
T N A	2	2	0	2	0	2
Tetryl	1	1	0	1	0	1
Ammonium picrate[b]	1	1	0	2	2	0
Picric acid	1	1	0	1	1	0
85/15 amatol	1	1	0	1	1	0
80/20 amatol				2	2	0
50/50 amatol	1	1	0	1	0	1
80/20 sodatol				2	2	0
60/40 sodatol	1	1	0	1	0	1

[a] Ingredients of the perchlorate explosives include:
No. 1 ammonium and potassium perchlorates, ammonium nitrate, aromatic nitro compounds, and carbonaceous combustible material.
No. 2 ammonium perchlorate, aromatic nitro compounds, and carbonaceous combustible material.

[b] A test with a carborundum shoe gave no unfavorable results.

Table 2 gives the results of tests of two samples of explosives with the steel shoe and with a steel shoe faced with Aloxite cloth No. 3½, grit 24. The height of fall was varied, but the other conditions were the same as in Table 1.

TABLE 2.—*Pendulum friction tests with different heights of fall.*

Designation of group.	Steel shoe. Number of explosives.				Aloxite 3½, grit 24. Number of explosves.			
	Tested.	Passed.	Failed.	Height of fall.	Tested.	Passed.	Failed.	Height of fall.
				Meters.				*Meters.*
T N A	1	0	1	2.0	1	1	0	2.0
	2	0	2	1.5				
	1	0	1	1.0				
	1	1	0	.5				
T N T					2	2	0	2.0
					1	1	0	1.5
					1	1	0	1.0
					1	1	0	.5

Table 3 gives the results of tests, with the wood-fiber shoe and the steel shoe, of a sample of 40 per cent straight dynamite, at normal temperatures, the height of fall and the weights being varied.

TABLE 3.—*Pendulum friction tests with variation in height of fall and added weight.*

Designation of group.	Wood-fiber shoe. Number of explosives.					Steel shoe. Number of explosives.				
	Tested.	Passed.	Failed.	Height of fall.	Added weight.	Tested.	Passed.	Failed.	Height of fall.	Added weight.
				Meters.	*Kg.*				*Meters.*	*Kg.*
Nitroglycerin dynamite, 40 per cent straight.	1	1	0	2.0	20	1	0	1	2.0	20
	1	1	0	1.5	20	1	0	1	1.5	20
	1	1	0	1.0	20	1	0	1	1.0	20
	1	1	0	.5	20	1	0	1	.5	20
						1	0	1	2.0	0
						1	0	1	1.5	0
						1	1	0	1.0	0
						1	1	0	.5	0

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Table 4 gives the results of tests, with the wood-fiber shoe and the steel shoe, of four samples of explosives at normal and high temperatures, other conditions being the same as in Table 1.

TABLE 4.—*Pendulum friction tests at normal and at high temperatures.*

Designation of group.	Wood-fiber shoe. Number of explosives.				Steel shoe. Number of explosives.			
	Tested.	Passed.	Failed.	Temperature.	Tested.	Passed.	Failed.	Temperature.
				°C.				°C.
80/20 amatol					2	2	0	15–18
					2	2	0	60–65
					2	2	0	90–95
80/20 sodatol					2	2	0	15–18
					2	2	0	58–65
					2	2	0	88–95
Gelatin dynamite, 40 per cent strength	2	2	0	55–63	1	0	1	62
Nitroglycerin dynamite, 40 per cent straight	2	2	0	55–65				

Table 5 gives the results of tests, with the wood-fiber shoe and the steel shoe, of samples of seven foreign explosives under the same conditions as in Table 1.

TABLE 5.—*Pendulum friction tests of foreign explosives.*

Designation of group.	Wood-fiber shoe. Number of explosives.			Steel shoe. Number of explosives.		
	Tested.	Passed.	Failed.	Tested.	Passed.	Failed.
Foreign explosives:[a]						
English explosives[b]—						
E	1	1	0	1	0	1
F	1	0	1	1	0	1
G				1	1	0
H				1	1	0
I				1	1	0
J				1	1	0
Mexican explosive—						
K	1	1	0			

[a] Ingredients of the explosives designated E, F, G, etc., include:
E. Dinitrotoluene, mononitronaphthalene, castor oil, potassium chlorate.
F. Potassium chlorate, nitrated resin.
G. Nitroglycerin, nitrotoluene, castor oil, nitrocellulose, ammonium nitrate, carbonaceous combustible material.
H. Ammonium nitrate, trinitrotoluene, mononitronaphthalene.
I. Resin, ammonium nitrate, potassium nitrate.
J. Trinitrotoluene, ammonium nitrate, carbonaceous combustible material.
K. Nitroglycerin, sodium and barium nitrates, carbonaceous combustible material.

[b] Designation used on pp. 275–302, Bull. 66, Bureau of Mines.

SUMMARY OF RESULTS.

1. Tests with the steel shoe are much more severe than tests with the wood-fiber shoe.

This conclusion is particularly proved by Table 3, in which 40 per cent straight dynamite passed the test at 2.0 meters fall and 20 kilograms added weight with the wood-fiber shoe, but failed with the steel shoe at 0.5 meters fall and 20.0 kilograms added weight, and 1.5 meters fall with no added weight. Moreover, the record shows that 40 explosives failed under test with the steel shoe but passed the test with the wood-fiber shoe, but for no explosive was the reverse true.

2. All the explosives tested with the wood-fiber shoe passed the test except 10 potassium-chlorate explosives and one perchlorate explosive.

3. Of 267 samples tested with the steel shoe, 55 failed to pass the test.

4. An inspection of results of tests of commercial explosives with the steel shoe shows that of the explosives submitted for permissibility tests, black blasting and ignition powders, blasting gelatin, ammonia dynamites, and organic nitrate explosives (other than nitroglycerin) are not as sensitive to frictional impact as the nitroglycerin dynamites and the gelatin dynamites.

5. An inspection of the results of tests of military explosives with the steel shoe shows that T N A, tetryl, 50/50 amatol, and 60/40 sodatol are more sensitive to frictional impact than T N T, picric acid, ammonium picrate, 85/15 amatol, 80/20 amatol, and 80/20 sodatol.

6. An inspection of the tests of T N A, in Table 2, and of 40 per cent straight dynamite with the steel shoe, in Table 3, shows that increasing the height of fall increases the severity of the test.

7. An inspection of the tests, in Table 3, of 40 per cent straight dynamite with the steel shoe shows that decreasing the added weight decreases the severity of the test.

8. An inspection of the tests in Table 4 shows no discrimination can be made on the basis of increasing the temperature.

9. Potassium chlorate explosives have proved extremely sensitive to frictional impact even when the wood-fiber shoe is used.

Those potassium chlorate explosives that passed the pendulum friction test were rendered sufficiently insensitive to friction by adding an adequate quantity of mineral oil, vegetable oils, and aromatic nitro compounds, or by reducing the potassium chlorate to a small percentage.

One potassium chlorate explosive (O) was made so insensitive that it would not detonate in the open with a No. 6 electric detonator.

10. That the pendulum friction device, as adopted by the Bureau of Mines, is not too severe is indicated by the fact that one of the potassium chlorate explosives which passed the test has on more than one occasion exploded prematurely during manufacture and use.

On the other hand, potassium chlorate explosives of the general type of E which failed to pass the pendulum friction test exploded prematurely on several occasions in use, although only a few tons had been manufactured and used.

11. The sensitiveness of potassium chlorate explosives to friction is greatly increased by the presence of pyrite-bearing coal.

PUBLICATIONS ON INVESTIGATIONS OF EXPLOSIVES.

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